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Full Research Article

The evaluation of Ecosystem Services production: an application in the Province of Ferrara

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Abstract. This paper presents an evaluation of the provision of Ecosystem Services (ES). The analysis is based on the design of a framework suitable to be translated into a multi-criteria evaluation process, followed by empirical testing. It focuses on the different categories of ES and applies a set of non-overlapping indicators available from existing statistical sources. The framework is applied in a traditional cultural landscape, the Province of Ferrara, situated in the Emilia-Romagna region of Italy. To develop an applicable framework, we have chosen a set of ES indicators from the Millennium Ecosystem Assessment. According to the results and based on the indicators used in each category, the provision of cultural and provisioning services is high in all of the municipalities, while there is greater diversity in the provision of regulating and supporting services. A key challenge in our analysis was related to the lack of information on the actual provision of ES at the municipality level, which led to a significant use of proxy indicators. Use of improved datasets, explicit consideration of policy scenarios and accounting for local priorities about ES provision have been identified as the most relevant avenues for future research in this area.

Keywords. Ecosystem Services, evaluation, indicators, multi-criteria analysis, classification

JEL Codes. Q57, C38

1. Introduction

The ecosystem concept describes the interrelationships between living organisms and the non-living environment. *"An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit"* (MEA, 2005). There is a full range of ecosystems, from natural forests, to ecosystems managed and modified by humans, such as agricultural land. Ecosystems provide a variety of benefits to people that are divided into market and non-market ecosystem goods or ecosystem services (ES) and classified in multiple ways.

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The Millennium Ecosystem Assessment Framework (MEA, 2003) identified four categories of ES: (1) provisioning services, such as food and water; (2) regulating services, such as flood and disease control; (3) supporting services, such as nutrient cycling; and (4) cultural services, such as spiritual, recreational, and cultural benefits. Following the Economics of Ecosystems and Biodiversity (TEEB, 2010a), ES are the direct and indirect contributions of ecosystems to human well-beings and are also categorized into four types: provisioning, regulating, habitat and cultural services. A new classification of ES is currently under development at the international level by the Common International Classification of Ecosystem Services (CICES, 2013). According to CICES, there are three types of services: provisioning, regulation (maintenance), and cultural services.

The concept of ES is being integrated into current biodiversity policies at the global and European levels (EC, 2009; Perrings *et al.*, 2011). The EU has adopted an ambitious strategy to halt the loss of biodiversity and ES by 2020 (EC, 2010b, 2011). There are 6 main targets, and 20 actions to help Europe reach its goal. Target 2 focuses on maintaining and enhancing ES and restoring degraded ecosystems by incorporating green infrastructure into spatial planning.

Improved ways and methods for ES quantification, mapping and assessment are needed to investigate the number and quality of ES produced by individual ecosystems and to increase the ability to feed such knowledge into policy design (TEEB, 2010b). While provisioning ES can often be directly quantified thanks to the availability of primary data, for other ecosystem services the collection of such information is often impossible (Maes *et al.*, 2015). Thus, for most regulating, supporting, and cultural services, researchers must rely on proxies for their quantification. As a result, altogether, data on quantifiable ES remain limited and only a small number of indicators are being used for those that cannot be measured directly (Feld *et al.*, 2010, 2009; Layke *et al.*, 2012). Reviews of indicators used for ES are now available from the literature and contribute to developing reliable indicators for modelling, as well as for bridging current data gaps (Cowling *et al.*, 2008; Egoh *et al.*, 2012)few studies are embedded in a social process designed to ensure effective management of ecosystem services. Most research has focused only on biophysical and valuation assessments of putative services. As a mission-oriented discipline, ecosystem service research should be user-inspired and user-useful, which will require that researchers respond to stakeholder needs from the outset and collaborate with them in strategy development and implementation. Here we provide a pragmatic operational model for achieving the safeguarding of ecosystem services. The model comprises three phases: assessment, planning, and management. Outcomes of social, biophysical, and valuation assessments are used to identify opportunities and constraints for implementation. The latter then are transformed into user-friendly products to identify, with stakeholders, strategic objectives for implementation (the planning phase.

Several studies have assessed changes in land use and their connection with the provision of ES (Carreño *et al.*, 2012; Fontana *et al.*, 2013; Silvert, 2000). In many cases, their output includes environmental and land use information that are connected to landscape features, although few yield a direct assessment of changes in ES provision (Burkhard *et al.*, 2012; Swetnam *et al.*, 2011). According to de Groot *et al.* (2010), ES approaches and ES valuation efforts have changed the terms of discussion on nature conservation, natural resource management, and other areas of public policy. These efforts have strengthened both public and private sector development strategies and improved environmental outcomes (de Groot, 2006; de Groot *et al.*, 2002).

The multidimensional logic of ES seems highly consistent with approaches based on Multi-Criteria Decision Analysis (MCDA). MCDA is a general framework for supporting complex decision-making situations with multiple and often conflicting objectives. Regarding ES evaluation, MCDA methods have been applied as decision support systems that integrate economic and noneconomic values (Newton *et al.*, 2012), used as approaches for cost-benefit analysis (Wegner and Pascual, 2011), or as a methodological framework for addressing value dimensions related to ES (Mendoza and Prabhu, 2003). Oikonomou *et al.* (2011) proposed a conceptual framework that combines ecosystem function analysis, multi-criteria evaluation and social research methodologies for introducing an ecosystem function-based planning and management approach. Ananda and Herath (2009) provided a review of research contributions on forest management and planning.

The objective of this paper is to evaluate the provision of ecosystem services focusing on the different categories of ES and applying a set of non-overlapping indicators available from secondary data sources. The approach used is based on the outranking method Preference Ranking Organisation Methods for Enrichment Evaluations (PROMETHEE). To evaluate the provision of ecosystem services, we used a traditional cultural landscape, the Province of Ferrara, situated in the Emilia-Romagna region and a set of ES from the Millennium Ecosystem Assessment Framework as criteria for the evaluation. The area consists of 26 municipalities, comprising the urban centre of Ferrara and adjoining agricultural lands within the ancient and vast Po River Delta. The area is characterised by historical-cultural locations, the surrounding landscape and protected areas of natural importance.

In the present study, along with the application of PROMETHEE II, a comparison and ranking of the 26 municipalities of the province is performed, based on the selected ES indicators. Different studies have used ranking approaches as a tool to evaluate ES. At times those tools are used as part of a larger ES assessment process that can involve simultaneously identifying ES and drivers of change, as well as ranking the most important services (López-Marrero and Hermansen-Báez, 2011; Shelton, 2001). The model assumes that the criteria are equally important, i.e. they did not use any weighing approach to reflect the relative preferences of decision makers.

The structure of this paper is as follows: the following section describes the PROMETHEE multi-criteria analysis framework; in the third section (Application), the case study and the selected ES indicators are introduced. In the fourth section, we present the results of the application of the PROMETHEE method for the evaluation of the provision of the ES in the Province of Ferrara. In the discussion sections, the key challenges as well as difficulties and limitations in our analysis are summarized, followed by a final concluding section.

2. Methodology

Among the various MCDA methods and the different software applications available, we used PROMETHEE II, which applies the outranking method and provides a complete ranking of a discrete set of possible alternatives, from the best to the worst, using the concept of net flow (Brans and Mareschal, 2005; Brans and Vincke, 1985). It is well adapted to problems where a finite number of alternatives are to be ranked whilst considering several and sometimes-conflicting criteria (Brans *et al.*, 1998). In addition, the mathematical model is relatively easy to understand and is capable of determining preferences among multiple decisions (Vinodh and Jeya Girubha, 2012). PROMETHEE, unlike other outranking methods, does not aggregate good scores on some criteria and bad scores on others (it is non-compensatory), uses less pairwise comparisons, does not have the artificial limitation of rigid scoring systems (e.g. the use of a 9-point scale for evaluation) and allows more flexibility in the determination of the weights (Albadvi, 2007).

A considerable number of successful applications has been treated by the PROMETHEE methodology in various fields such as banking, manpower planning, water resources, investments, medicine, chemistry, health care, tourism, and dynamic management (Andreopoulou *et al.*, 2011, 2009; Behzadian *et al.*, 2010, 2013; Olson, 2001; Olson *et al.*, 1998). Wolfslehner *et al.* (2011) based on a PROMETHEE II algorithm, calculated relative sustainability impact rating. Moreover, Madlenera *et al.* (2007) used the PROMETHEE method to compare and rank different energy scenarios according to 16 economic, social, environmental, and technological criteria.

Regarding ES evaluation and assessment, Segura *et al.* (2015) applied a PROMETHEE-based method to obtain new composite indicators for provisioning, maintenance and 'direct to citizen services'. Fontana *et al.* (2013) have also used PROMETHEE to compare land use alternatives considering ES as criteria. Queiruga *et al.* (2008) applied PROMETHEE to rank Spanish municipalities according to their appropriateness for the installation of waste electrical and electronic equipment recycling plants. Moreover, Vaillancourt and Waaub (2004) used PROMETHEE to rank regions in order to allocate greenhouse gas emission rights. Chatzinikolaou *et al.* (2013) applied PROMETHEE for the comparison and ranking of EU rural areas based on social sustainability indicators. Hermans *et al.* (2007) used PROMETHEE to evaluate river management alternatives and elicit preferences to rank and compare individual and group preferences. PROMETHEE has also been used in environmental management for ranking and selecting environmental projects (Yan *et al.*, 2007) and environmental impact assessments for ranking waste management alternatives and air quality/emission problems (Huang and Wang, 2014).

For the implementation of the method the following procedure is recommended.

2.1 Problem definition

The procedure proposed by Brans *et al.* (1986) starts by considering the multi-criteria problem (1):

$$Max \{f_1(a),\ldots f_k(a),\backslash\ a \in K\} \tag{1}$$

where K is a finite set of actions and $f_i, i = 1,\ldots k$, are k criteria to be maximized.

The PROMETHEE methods include two phases (Roy, 1991):

- the construction of an outranking relation on K,
- the exploitation of this relation in order to provide an answer to (1).

In the first phase, a valued outranking relation based on a generalization of the notion of criterion is considered: a preference index representing the preferences of the alternatives is defined. The exploitation of the outranking relation is realised by considering a positive and a negative flow for each action.

2.2 Identification of alternatives

The procedure is carried out by choosing among different elements to be examined and assessed using a set of criteria. These elements are called actions or alternatives. In the present study, the "alternatives" to be examined and evaluated are the 26 municipalities of the Province of Ferrara. In this sense, the concept of an alternative is used to identify different objects to compare rather than reciprocally excluding courses of action.

2.3 Defining a set of criteria.

The criteria represent the tools that enable alternatives to be compared from a specific point of view. The alternatives are compared pairwise under each criterion. Two alternatives a and b, can express an outright preference, a weak preference or indifference. In the present study, criteria are represented by a set of ES indicators, which are presented in the next section.

2.4 Evaluation matrix

Once the set of criteria and the alternatives have been selected, then the payoff matrix is built. This matrix tabulates, for each criterion–alternative pair, the quantitative and qualitative measures of the effect produced by that alternative with respect to that criterion.

2.5 Determining the multi-criteria preference index

The preference structure of PROMETHEE is based on pairwise comparisons. The preference index, for each pair of alternatives $a, b \in K$ (where K is the set of alternatives) ranges between 0 and 1. The higher it is (closer to 1), the higher the strength of the preference for *a* over *b*. When the pairs of alternatives *a* and *b* are compared, the outcome of the comparison is expressed as follows:

- P(a,b) = 0 means indifference between *a* and b, or no preference of *a* over *b*;
- P(a,b) ~ 0 means a weak preference of *a* over *b*;
- P(a,b) ~ 0 means a strong preference of *a* over *b*;
- P(a,b) = 1 means a strict preference of *a* over *b*;

H(d) is an increasing function of the difference d between the performances of alternatives *a* and *b* on each criterion and d is the deviation between the evaluations of two alternatives on each criterion (2) (Vincke, 1992).

$$H(d) = \begin{cases} P(a,b), d \geq 0, \\ P(b,a), d \leq 0. \end{cases} \qquad (2)$$

2.6 Weighting

Once the preference function P_i (i= 1,2,3,…n represent the criteria) is defined, the weights of each criterion must be determined. The weights π represent the relative importance of the criteria used, if all criteria are equally important then the value assigned to each of them will be identical (Hermans and Erickson, 2007). The multi-criteria indicator of preference $\Pi(a,b)$ which is a weighted mean of the preference functions $P(a,b)$ with weights π_i for each criterion, express the superiority of the alternative a against alternative b after all of the criteria are tested. The values of $\Pi(a,b)$ are calculated using the following equation (Brans and Mareschal, 2005) (3):

$$\Pi\left(a,b\right)=\frac{\sum_{i=1}^{k}\pi_i P_i\left(a,b\right)}{\sum_{i=1}^{k}\pi_i} \tag{3}$$

In the present study, the shape of the H(d) function selected is the Gaussian form (Koutroumanidis *et al.*, 2002) (4):

$$H(d) = 1 - exp\{-d^2/2\sigma\}^2 \tag{4}$$

where d is the difference among the alternatives a and b $[d = f(a) = f(b)]$ and σ is the standard deviation of all differences d and for each criterion. The model simulates 50 scenarios of weights and on each scenario of weights ten scenarios on the standard deviation of s distribution of Gauss. The ten scenarios σ oscillate from 0.25 s until 2.5 s with step 0.25 s, where s the standard deviation of all differences d for each criterion. The model formulates 500 different net flows for each alternative and calculate the medium value (Mareschal and Brans, 1991).

2.7 Ranking the alternatives

The traditionally non-compensatory models include some for which the preferences are aggregated by means of outranking relations. The ranking of alternatives under PROMETHEE uses the positive flow (5), which indicates the preference of the alternative a above all others, the negative flow (6) that indicates the preference of all of the alternatives compared with the alternative a, and the net outranking flow (7), which is the balance (difference) between the positive and the negative flows.

$$\varphi^+(a) = \Sigma_{b\in k}\,\Pi(a,b) \tag{5}$$

$$\varphi^-(a) = \Sigma_{b\in k}\,\Pi(b,a) \tag{6}$$

$$\varphi(a) = \varphi^+(a) - \varphi^-(a) \tag{7}$$

3. Application in the Province of Ferrara

3.1 Case study

The study area is the Province of Ferrara, located on the eastern side of the Emilia-Romagna region. It is composed of 26 municipalities covering an area of 2,632 km^2 and a total population of about 359,000 (Table 1). Extending to the Po River Delta, the province offers sceneries of rare charm and contains important Natura2000 sites: the river Po delta of the only true delta in Italy and contains a complex national wetlands system. The Natura 2000 site's important coastal habitats and water bird species are under threat from the eutrophication of the lagoon waters, due to the accumulation of underwater vegetation. The Regional Park of the Po Delta is part of a system of the protected areas in the region. The park is divided into six "stations" around the southern area of the Po Delta, which are characterised and differentiated by particular environmental and landscape features. All of the areas are characterised by a wonderful natural environment which have led to the development of human activities such as fishing, agriculture, tradition, culture and art. Agriculture and trade are the most important sectors in the area, followed by building and industry. The main environment-related activities are connected to habitat restoration and conservation, species protection habitat, management of selected critical areas and the elaboration of development plans (Marino *et al.*, 2014). The Rural Development Plan (RDP) of the Emilia-Romagna region has proposed different measures that contribute to the preservation of landscapes and focus on the delivery of ecosystem services. Specific RDP amendments include reinforced efforts contributing to water management, restructuring of the dairy sector, improved broadband internet infrastructure in rural areas, biodiversity, climate change mitigation and adaptation. Furthermore, thanks to this policy action the park is improving agriculture in a positive and sustainable manner, e.g. organic production. Since reclaimed lands have replaced the wetlands, agriculture has replaced the typical landscape elements (marshes, pine woods) with large extensions of embankments and water channels (Viaggi *et al.*, 2014).

Table 1. Municipalities in the Province of Ferrara

Code	Territory	Population
X1	Argenta	22,087
X2	Berra	5,088
X3	Bondeno	14,864
X4	Cento	35,444
X5	Codigoro	12,337
X6	Comacchio	22,428
X7	Copparo	16,943
X8	Ferrara	131,842
X9	Formignana	2,802
X10	Goro	3,879
X11	Jolanda di Savoia	3,016
X12	Lagosanto	4,978
X13	Masi Torello	2,344
X14	Massa Fiscaglia	3,543
X15	Mesola	7,092
X16	Migliarino	3,670
X17	Migliaro	2,225
X18	Mirabello	3,420
X19	Ostellato	6,462
X20	Poggio Renatico	9,770
X21	Portomaggiore	12,190
X22	Ro	3,380
X23	Sant'Agostino	7,052
X24	Tresigallo	4,553
X25	Vigarano Mainarda	7,491
X26	Voghiera	3,823

Source: ISTAT and own elaboration

3.2 Selection of Ecosystem Service Indicators

Identifying consistent, quantifiable and comparable indicators supports the development of models and evaluation of ES. Determining what to measure and what method to use is directly related to the availability of data and the type of indicator. However, mainstreaming ES concepts more broadly will require information designed for policy-makers, including data, decision support tools, and "indicators" – information that condenses complexity to a manageable level and informs decisions and actions (Bossel, 2002). Although global indicators provide an overview that allows for a regional or national scale analysis, in many cases there is limited information available. The demand for ecosystem services is increasing in many European countries, yet there is still a scarcity of data on values at regional scale (Gatto *et al.*, 2013). As a result, proxy indicators are often used as surrogates. Proxy methods are especially used for cultural services, as these services are difficult to directly measure and model. Yet there are limitations to their use. Several reviews have tried to assess and summarize the use of indicators to provide information (Feld *et al.*, 2009; Layke *et al.*, 2012; van Zanten *et al.*, 2014). Moreover, Egoh *et. al.* (2007) provided an extensive literature review of studies, excluding sub-global assessments, and identifying ES indicators.

The selected ES indicators in the present study are those that are considered to give sufficient information on the benefits that people derive from an ecosystem (de Groot *et al.*, 2012) among those available in the regional databases (i.e. publicly available for the entire Emilia-Romagna region). This was partly done on purpose to assess the usability of secondary data to assess the provision of ES at the municipality level. The data obtained from statistics usable as proxies of ES provision in the area were provided by the National Institute of Statistics (ISTAT), other statistical databases (EUROSTAT; FAOSTAT) and regional sources (E-R; PR Ferrara). Provisioning and cultural services have the greatest number of indicators compared to other services. Land cover proved to be an important indicator for all four categories of services. Land cover data typically contains land use, such as agricultural land, vegetation types, and forest. The selected ES indicators are presented in Table 2, divided according the different categories of ES. (See Appendix for more detailed information).

3.3 Provisioning services

Among the studies that evaluate provisioning services, food provision receives the most attention. Indicators used for food production include agricultural production (potential) measured in hectares of land, livestock numbers or vegetation suitability for fodder production and grain yield (Fezzi *et al.*, 2014; Palacios-Agundez *et al.*, 2015; Pohle *et al.*, 2013). Other provisioning services directly linked to human well-beings are crop production, capture fisheries, and livestock production (Pohle *et al.*, 2013). In the present study, the number of agricultural holdings, the utilised agricultural area and the area of arable land have also been used as indicators to measure food provision. Regarding raw materials, the indicator used is the wooded area. Another service is water provision. It is important to note that water provision or supply is not the same as water regulation. The latter is the process through which clean water becomes available, whilst water provision or supply is water that

Table 2. Selected Ecosystem Services Indicators

Ecosystem Service category (MEA)	Ecosystem Service group	Ecosystem Service Indicators		
		Code	Indicator	Source
Provisioning	Food provision	K1	Number of agricultural holdings	Eurostat -2012
	Food provision	K2	Utilised agricultural area	Eurostat-2012
	Food provision	K3	Arable land	Faostat -2010
	Water provision	K4	Irrigated area	Istat-2010
	Water provision	K5	Irrigated area - surface water (natural and artificial basins, lakes, rivers or waterflows)	Istat-2010
	Water provision	K6	Irrigated area - underground water	Istat-2010
	Raw materials	K7	Wooded area	Istat-2010
Regulating	Regulation of Water	K8	Volume of irrigation water	Istat-2010
	Regulation of Water	K9	Volume of irrigation water - surface water (natural and artificial basins, lakes, rivers or water flows)	Istat-2010
	Regulation of Water	K10	Aqueduct, irrigation and restoration consortiums	Istat-2010
Supporting	Biological Control	K11	Organic agricultural area	Istat-2010
	Production Quality	K12	Agricultural area of PDO and/or PGI farms	Istat-2010
Cultural	Recreation and tourism	K13	Visitors Arrivals	PR Ferrara -2010
	Recreation and tourism	K14	Italian visitors, Arrivals	PR Ferrara -2010
	Recreation and tourism	K15	Foreign visitors, Arrivals	PR Ferrara -2010
	Aesthetic enjoyment	K16	Collective accommodation establishments	E-R -2010
	Aesthetic enjoyment	K17	Hotels and similar establishments	E-R -2010
	Aesthetic enjoyment	K18	Holiday and other short-stay accommodation, camping grounds, recreational vehicle parks and trailer parks	E-R -2010
	Recreation and tourism	K19	Number of active enterprises (total)	E-R -2010
	Recreation and tourism	K20	Number of active enterprises in agriculture (crop and animal production, support activities to agriculture and post-harvest crop activities, forestry and logging, fishing and aquaculture)	E-R -2010
	Recreation and tourism	K21	Number of active enterprises in accommodation and food services activities	E-R -2010
	Recreation and tourism	K22	Number of farms with other gainful activities (agritourism, recreational and social activities, initial processing of agricultural products, renewable energy production, wood processing)	E-R -2010

Source: MEA and own elaboration.

is already available for use. A number of previous ecosystem service studies have used water production, i.e. the volume of water produced by area, as an ES or as a surrogate for an ES. Water provision is measured through different indicators that include surface or ground water availability (Fan and Shibata, 2014; Karabulut *et al.*, 2015). In the present study, the indicators for water provision are related to the irrigated area, by distinguishing surface water use (natural, artificial basins, lakes, rivers or waterflows) from underground water.

3.4 Regulating services

Generally, there is a lower number of indicators for regulating services as they are not directly consumed or physically perceived by people. The majority of studies that evaluate regulating services has evaluated in particular climate and water regulation (Larondelle *et al.*, 2014; Pan *et al.*, 2014). Climate regulation services mainly relate to the regulation of greenhouse gases; therefore, the indicators for climate regulation included carbon storage, carbon sequestration, and greenhouse gas regulation. Another common regulating service that is mapped is water flow regulation (Simonit and Perrings, 2011; Stürck *et al.*, 2015). Indicators used for mapping water flow regulation are nutrient retention and land cover (Boyanova *et al.*, 2014; Schmalz *et al.*, 2015). The total benefit to people from water supply is a function of both the quantity and quality. However, due to the lack of suitable municipality scale data on water quality for quantifying the service, proxies are used as an estimation of the benefit (Egoh *et al.*, 2008; Müller and Burkhard, 2012). In the present study, the indicators used for water regulation are: a) the volume of irrigation water- surface water (natural and artificial basins, lakes, rivers or waterflows); and b) underground, aqueduct, irrigation and restoration consortiums.

3.5 Supporting services

This category of ES, according to the conceptual framework of the Common International Classification of Ecosystem Services (CICES), is categorized under regulating and maintenance services. The few indicators that have been identified relate to species and habitat. The comparatively lower numbers of indicators for supporting services could be attributed to the lack of information available on these services (Barbier, 2007, 2013). The identification of indicators for services such as life cycle maintenance and maintenance of genetic diversity are rather generic and it is hence difficult to find suitable indicators (Balvanera *et al.*, 2006; Swinton *et al.*, 2007). The most common examples include indicators for primary production, production quality and controls and nutrient cycling (Benayas *et al.*, 2009; Crafford and Hassan, 2013). In the present study, the indicator used for biological control is the organic agricultural area and the area of protected designation of origin (PDO farms) and the area of protected geographical indications (PGI farms) are applied for production quality.

3.6 Cultural services

Cultural services are non-material benefits that include recreation, spiritual and aesthetic value. Identifying an indicator that represents these challenges, and that is spatially represented, is fundamental for the measurement of the capacity of ecosystems to generate human benefits. Schaich *et al.* (2010) proposed an alternative approach to fill the knowledge gaps in cultural services that links ES research with cultural landscape research. This approach is based on the development of a well-being index based on indicators and metrics derived from existing measures of well-being. Groups of indicators described by suites of metrics are commonly aggregated to evaluate components of well-being. These indicators represent social cohesion, education, health, leisure time, safety and security (Guhn *et al.*, 2012; Huntington, 2000). The majority of these indicators describe the quantity and quality of ecosystems, economic drivers, and social inputs. However, these types of measures are not directly used in quantifying the delivery of ES. The individual indicators are usually used to develop composite measures and are based on quantitative values, such as generally recognised qualitative assessments (Smith *et al.*, 2013). The most common indicators for cultural services include recreation and ecotourism, which can be directly measured through a number count of visitors (Milcu *et al.*, 2013). Visitor information can also be obtained from national statistics or from park inventories. In the present study, we used the number of foreign or Italian visitors. Indicators used for recreational activities vary among studies, from accommodation suitability and summer cottages, deer hunting and fishing to natural areas and forested area for recreational purposes (Naidoo *et al.*, 2011). Indicators include scenic sites, water bodies or forests as well as visitor numbers and accessibility to natural areas. In the present study, with respect to recreational activities, we used the active enterprises in agriculture, the active enterprises in accommodation and food service activities and the farms with other gainful activities, such as agritourism, recreational and social activities. Although these indicators are relatively easy to quantify, indicators for aesthetic and spiritual activities are still in the early stages of development and those that exist are difficult to quantify and compare between countries or regions (Eagles, 2002). In addition, in the present study, we used the collective accommodation establishments, hotels and similar establishments, holiday and other short-stay accommodations, campgrounds, recreational vehicle parks and trailer parks as proxy indicators for aesthetic services.

3.7 Application of PROMETHEE II

The initial stage is the evaluation matrix, which presents the performance of each alternative in relation to each criterion. In our analysis, the alternatives are the 26 municipalities of the Province of Ferrara (X1-X26, Table 1) and the criteria are the 22 ES indicators (K1-K22, Table 2). The performance of each alternative in relation to each criterion is presented in Table A1 and the evaluation matrix is presented in Table A2 (See Appendix). Using the data contained in the evaluation matrix, the alternatives are compared pairwise with respect to each criterion.

The second stage involves the exploration of the outranking relation. The results are expressed by the preference functions, which are calculated for each pair of options. In the present study, the model assumes that the criteria are equally important and simulates different scenarios for weighing accordingly.

In the final stage, two alternatives (a,b) are compared with each other and each one is assigned two values of flows. The positive flow expresses the total superiority of the alternative against all of the other alternatives for all of the criteria. The negative flow expresses the total superiority of all of the other alternatives against alternative for all of the criteria. $\Phi(x)$ the net flow of each alternative (the difference between the positive and the negative flow) and is used to obtain the final evaluation.

4. Results

Table 3 presents the evaluation of the study areas, as obtained from the net flows. According to the value of the net flow, the 26 municipalities are divided into 5 groups. The first group of municipalities, characterised by high positive net flows, consists of: Comacchio, Goro, Argenta and Jolanda di Savoia, all located in the western area of the province. Comacchio and Argenta have the highest values in the indicators that represent cultural services, such as foreign visitors, hotels and similar establishments, the number of active enterprises providing accommodation and food service activities and the number of farms with other gainful recreational activities. Goro has the highest rate in the number of active enterprises in agriculture (crop and animal production, support activities to agriculture) and the highest number of farms with other gainful agricultural activities. Moreover, Jolanda di Savoia has the highest rate in the agriculture area of PDO and/o PGI farms. These features are indeed connected to key features of the area. Since a large part of the territory is within the Po Delta Park, it contains important Natura2000 sites. Visits to the area increase considerably during the summer months. During this period, demand for beaches, areas of high naturalistic value and historical sites has resulted in the development of receptive structures, such as rental houses, hotels, camping areas, beaches with restaurants, etc. Summer tourism is also an important market for horticultural farms (most of which are close to the seaside).

Table 3. Classification of the 26 municipalities

	Municipality	Net Flow (Φ)
1	Comacchio	2,888194373
2	Goro	2,543589598
3	Argenta	1,997682356
4	Jolanda di Savoia	1,190854183
5	Migliaro	0,720865791
6	Codigoro	0,709070084
7	Vigarano Mainarda	0,694387495
8	Bondeno	0,614876652
9	Massa Fiscaglia	0,402104543
10	Portomaggiore	0,257389617
11	Mesola	0,194863948
12	Poggio Renatico	0,146803521
13	Cento	0,008314139
14	Ro	-0,14634547
15	Sant'Agostino	-0,21655112
16	Migliarino	-0,27198083
17	Ostellato	-0,28124392
18	Lagosanto	-0,30769265
19	Mirabello	-0,68414923
20	Masi Torello	-1,00385534
21	Ferrara	-1,14179801
22	Voghiera	-1,26554807
23	Formignana	-1,32908587
24	Copparo	-1,34379219
25	Tresigallo	-2,09068952
26	Berra	-2,28626409

Source: own elaboration

The second group of municipalities, with a positive but lower net flow, are Migliaro, Codigoro, Vigarano Mainarda and Bondeno. Migliaro and Codigoro, located in the western area of the province, have high rates in the indicators that represent cultural services, such as Italian visitors, holiday and short-stay accommodation, camping grounds, recreational vehicle parks and trailer parks. Migliaro also has the highest rate in organic agricultural area. Moreover, Bondeno and Vigarano Mainarda, located in the eastern area of the province, have the highest rate in the irrigated area from natural and artificial basins.

The third group, with positive net flows around 0, consists of Massa Fiscaglia, Portomaggiore, Mesola, Poggio Renatico and Cento. Small negative flows around 0 distinguish the fourth group including Ro, Sant'Agostino, Migliarino, Ostellato Lagosanto, and Mirabello. These groups of municipalities are in the middle of this evaluation, since the rates are neither extremely high nor particularly low. Municipalities with negative net flows have low rates in more than one ecosystem system indicator, like agricultural farms with other gainful activities such as agritourism, recreational and social activities, initial processing of agricultural products or renewable energy production and the agricultural area of PDO and/or PGI farms. These results are connected to key features of the area, since the main recreational activities in the area are related to habitat restoration and conservation and species protection habitat (especially birds) while other agricultural activities are seen negatively, mainly because of the negative effect on water quality.

The fifth and last group of municipalities, located in the central area of the province, (Masi Torello, Ferrara, Voghiera, Formignana, Copparo, Tresigallo and Berra) has negative net flows below -1. Berra has no organic agricultural area, hotels or similar accommodation services. Tresigallo has no wooded area. Formignana has no hotels or similar establishments. Other indicators with low rates are agricultural farms with other gainful activities such as agritourism, recreational and social activities, initial processing of agricultural products or renewable energy production and the agricultural area of PDO and/or PGI farms. There is the potential to modify/improve the landscape through different projects. For example, some such initiatives include: the evaluation of the economic impact of climate change on agriculture, conservation of natural areas, valorisation of local products, restoration of ecological areas as tourist attractions, restoration of forested areas, and the greening of farms to restore the traditional landscape).

5. Discussion

Due to its explorative nature, this study is subject to several weaknesses and a number of options for improvement. The main issue concerns the number of gaps in the ES metrics and indicators available at the regional level, with respect to the number and quality of indicators needed to reflect the ES approach in a comprehensive way. The most important challenge in our analysis was, accordingly, the lack of information with respect to the provision of ES at the regional level. The indicators available for most ES are not fully satisfactory in their ability to evaluate the quality and quantity of benefits provided. The number of ES indicators in each category varies significantly due to the different data availability and reliability. This prevented us from achieving a thorough understanding of the behaviour of individual services. In addition, due to data paucity, it was not possible to consider the interactions between specific services.

Another limitation in the application of PROMETHEE is that it did not use any weighing approach to reflect the relative preferences of potential decision makers or society. According to Macharis *et al.* (2004), the model assumed that the criteria were equally important and simulated different scenarios for appropriate weighing.

Moreover, we did not consider alternative scenarios of ES production. In this respect, there is potential for further research as the model could be used to simulate alternative scenarios based on post-2013 measures that can affect the supply or demand of ES. In that case, the model could involve stakeholder preferences with respect to the services to be provided and the indicators and criteria to assess the services.

For the valuation of ES, identification of relevant stakeholders is a critical issue (Hein et al., 2006). In almost all steps of the valuation procedure, stakeholder involvement is essential to determine main policy and management objectives and to identify the main relevant services and assess their values. This is an aspect that could be strengthened in further research.

6. Conclusions

The objective of this paper is to evaluate the provision of ecosystem services in a traditional cultural landscape in the Province of Ferrara. It is mostly an explorative paper intended to verify the possibility of using available secondary data at the municipality level to comparatively assess ES provision. The case study area is characterised by historical-cultural sites, agricultural areas and protected areas of natural importance. From the final outranking, we can observe that the provision of ecosystem services varies greatly from one municipality to the next. Regarding the various ES categories, all of the municipalities offer a significant number of provisioning and cultural services, mainly connected to recreational opportunities; on the contrary, there is greater diversity in the provision of regulating and supporting services. This evaluation can support the characterisation of agricultural lands in terms of the provision of multiple ES. This exercise also contributes to the discussion surrounding the public goods provided by agriculture and efforts toward a better use of resources and can ultimately improve the spatial targeting of policy measures.

A key challenge of ecosystem management is determining how to manage multiple ES across landscapes. Enhancing important provisioning ES, such as food and timber, often leads to trade-offs between regulating and cultural ES, such as nutrient cycling, flood protection, and tourism.

In terms of further research, the model can also be used to simulate alternative scenarios, based on future agricultural policies that may affect the supply or demand of ES (EC, 2010b). Alternative scenarios could be built based on the provisions of the new programming period affecting landscape structure and behaviours related to ES. The objectives of the CAP 2014-2020 are oriented towards the sustainable management of natural resources and climate action (e.g. 'greening' in the first pillar) (Viaggi, 2015). In particular, post-2013 measures include agri-environmental payments to improve ES, mechanisms that can affect landscape management, such as water and nature conservation measures, and other mechanisms promoting demand for ES, such as rural tourism. This should also provide an opportunity for more focused evaluations that address the data gaps and indicator limitations observed in this study.

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Appendix

Table A1. Ecosystem services provision.

	Number of agricultural holdings	Utilised agricultural area	Arable land	Irrigated area	Irrigated area - surface water (natural and artificial basins, lakes, rivers or waterflows)	Irrigated area - underground water	Wooded area
Argenta	777	23104,96	21202,5	7897	650,83	69,83	317,2
Berra	241	5005,19	4662,83	1692	422,35	37,98	38,17
Bondeno	587	12818,7	12156,22	2864	1588,8	61	22,7
Cento	459	4965,41	4561,23	503	256,98	32,85	4,34
Codigoro	327	10891,06	10769,79	6685	343,19	22,6	75,71
Comacchio	293	10033,64	9694,82	6406	1260,9	44,07	114,77
Copparo	677	11631,09	10465,28	2402	404,45	40,68	33,63
Ferrara	1604	27874,6	22799,17	7433	1744,5	591,27	86,82
Formignana	103	1720,67	1470,55	382	78,18	7,5	2,09
Goro	24	638,48	635,48	174	22	0	3
Jolanda di Savoia	199	8230,48	7991,19	3200	53,8	12	23,13
Lagosanto	68	2124,74	1981	1468	59,16	0	17,73
Masi Torello	98	1527,95	1316,11	349	7,2	0	16,64
Massa Fiscaglia	102	3042,2	3000,49	1017	57,06	13,6	1,77
Mesola	282	4698,31	4592,52	3375	32,58	0	11,7
Migliarino	92	2831,47	2382,05	1121	55,52	0	5
Migliaro	52	3111,55	3073,59	264	10,85	0	15,24
Mirabello	43	1293,97	1196,75	70,7	11,6	23,06	0
Ostellato	349	11857,18	11206,6	5738	490,46	61,99	8,69
Poggio Renatico	244	5894,04	5233,23	1423	538,62	121,05	15,26
Portomaggiore	324	10036,12	9166,19	2901	254,48	70,35	59,04
Ro	163	2756,83	2590,52	709	5,9	37,34	20,12
Sant'Agostino	168	2404,4	2134,56	414	196,09	23	0
Tresigallo	80	1436,99	1240,67	359	52,41	8,31	0
Vigarano Mainarda	177	3182,31	2538,07	638	353	200,76	9,54
Voghiera	214	3763,29	2814,05	1301	348,72	20,62	11,61

Table A1. Ecosystem services provision (continued).

	Volume of irrigation water	Volume of irrigation water - surface water (natural and artificial basins, lakes, rivers or waterflows)	Volume of irrigation water - underground water in or near the farm aqueduct, irrigation and restoration consortium	Organic agricultural area	Agricultural area of PDO and/or PGI farms	Visitors Arrivals
Argenta	22219871,85	1842392,49	18277528,04	6542	3169	5409
Berra	8888067,05	1295545,48	3634800,82	0	164	91
Bondeno	8721393,28	4753715,27	880400,95	100	563	898
Cento	1425067,73	785070,95	108623,73	18,3	56,5	11696
Codigoro	43698065,67	1058176,82	40023575,57	1389	426	3985
Comacchio	18585945,8	3681841,57	13115943,65	1140	651	455142
Copparo	10260339,76	1248347,74	3813132,4	143	451	4889
Ferrara	22737104,04	6201258,36	6654913,52	2535	440	175549
Formignana	1257376,39	290371,02	529924,59	5,2	18,7	88
Goro	514795,61	264000	236735,34	0	0	465
Jolanda di Savoia	28055933,9	138237,82	27293092,73	25,6	3802	56
Lagosanto	4133759,17	141047,59	2738931,48	0	16,3	358
Masi Torello	1019254,47	23917,94	83147,47	20,4	129	124
Massa Fiscaglia	3653570,09	476962,64	2930395,31	552	0	88
Mesola	8472806,43	60708,87	7768578,41	29,5	528	2944
Migliarino	3917812,87	94048,48	3562210,88	1126	88,7	1025
Migliaro	943095,47	28136,22	914959,25	2187	0	88
Mirabello	198455,23	35615,66	100623,67	0	0	88
Ostellato	18812898,76	1416033,01	16451586,06	435	28,1	5668
Poggio Renatico	3957393,46	1420865,38	2017315,88	6,2	93,5	271
Portomaggiore	8556809,49	843795,16	6507314,36	316	246	3328
Ro	2460678,75	21073,95	667629,1	29,8	11,9	97
Sant'Agostino	1241949,89	557231,38	572812,61	18,1	14,3	792
Tresigallo	1326476,31	139231,6	171284,57	108	85,3	1066
Vigarano Mainarda	1858061,51	995519,79	228545,16	13,9	41,9	2471
Voghiera	4077942,32	866873,9	161755,34	1,62	863	258

Table A1. Ecosystem services provision (continued).

	Italian Visitors, Arrivals	Foreighners Visitors, Arrivals	Collective accommodation establishments	Hotels and similar establishments	Holiday and other short-stay accommodation, camping grounds	Number of active enterprises (total)	Number of active enterprises in agriculture (crop and animal production,	Number of active enterprises in accomodation and food	Number of farms with other gainful activities (agritourism, recreational and social activities)
Argenta	4579	830	25	5	20	1347	16	89	80
Berra	79	12	0	0	0	260	9	13	14
Bondeno	735	163	9	2	7	748	16	50	19
Cento	9101	2595	16	7	9	2154	17	131	15
Codigoro	3244	741	14	5	9	837	56	60	22
Comacchio	365022	90120	107	27	80	2545	289	393	22
Copparo	4152	737	10	3	7	975	7	69	27
Ferrara	126404	49145	172	34	138	10860	30	697	64
Formignana	78	10	1	0	1	139	3	8	6
Goro	442	23	8	2	6	1197	1009	21	5
Jolanda di Savoia	56	0	3	0	3	130	6	13	11
Lagosanto	303	55	3	1	2	343	25	19	4
Masi Torello	114	10	5	0	5	152	0	10	6
Massa Fiscaglia	78	10	1	0	1	194	7	15	3
Mesola	2542	402	10	4	6	604	163	34	35
Migliarino	929	96	7	0	7	266	1	20	9
Migliaro	78	10	2	0	2	116	1	5	2
Mirabello	78	10	1	0	1	185	2	11	4
Ostellato	4788	880	10	2	8	363	10	27	16
Poggio Renatico	223	48	7	1	6	488	5	27	8
Portomaggiore	2969	359	10	1	9	759	6	55	30
Ro	93	4	4	0	4	161	4	14	12
Sant’Agostino	633	159	4	3	1	386	1	28	5
Tresigallo	807	259	3	2	1	268	2	18	4
Vigarano Mainarda	1758	713	7	3	4	390	4	28	7
Voghiera	206	52	3	0	3	273	5	15	13

Table A2. Evaluation matrix

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11
X1	10,03%	91,20%	91,77%	12,99%	8,24%	0,88%	1,37%	9,62%	8,29%	82,26%	28,31%
X2	3,11%	90,02%	93,16%	2,78%	24,95%	2,24%	0,76%	3,85%	14,58%	40,90%	0,0%
X3	7,58%	92,72%	94,83%	4,71%	55,48%	2,13%	0,18%	3,78%	54,51%	10,09%	0,78%
X4	5,92%	91,54%	91,86%	0,83%	51,07%	6,53%	0,09%	0,62%	55,09%	7,62%	0,37%
X5	4,22%	91,36%	98,89%	11,00%	5,13%	0,34%	0,70%	18,92%	2,42%	91,59%	12,76%
X6	3,78%	91,09%	96,62%	10,54%	19,68%	0,69%	1,14%	8,05%	19,81%	70,57%	11,36%
X7	8,74%	91,06%	89,98%	3,95%	16,84%	1,69%	0,29%	4,44%	12,17%	37,16%	1,23%
X8	20,70%	91,12%	81,79%	12,23%	23,47%	7,96%	0,31%	9,84%	27,27%	29,27%	9,09%
X9	1,33%	92,18%	85,46%	0,63%	20,48%	1,96%	0,12%	0,54%	23,09%	42,15%	0,30%
X10	0,31%	92,06%	99,53%	0,29%	12,63%	0,0%	0,47%	0,22%	51,28%	45,99%	0,0%
X11	2,57%	90,57%	97,09%	5,26%	1,68%	0,37%	0,28%	12,15%	0,49%	97,28%	0,31%
X12	0,88%	92,51%	93,23%	2,42%	4,03%	0,0%	0,83%	1,79%	3,41%	66,26%	0,0%
X13	1,27%	92,73%	86,14%	0,57%	2,07%	0,0%	1,09%	0,44%	2,35%	8,16%	1,33%
X14	1,32%	94,61%	98,63%	1,67%	5,61%	1,34%	0,06%	1,58%	13,05%	80,21%	18,15%
X15	3,64%	88,17%	97,75%	5,55%	0,97%	0,0%	0,25%	3,67%	0,72%	91,69%	0,63%
X16	1,19%	90,54%	84,13%	1,84%	4,95%	0,0%	0,18%	1,70%	2,40%	90,92%	39,77%
X17	0,67%	92,68%	98,78%	0,43%	4,11%	0,0%	0,49%	0,41%	2,98%	97,02%	70,27%
X18	0,56%	86,05%	92,49%	0,12%	16,42%	32,64%	0,0%	0,09%	17,95%	50,70%	0,0%
X19	4,50%	93,54%	94,51%	9,44%	8,55%	1,08%	0,07%	8,14%	7,53%	87,45%	3,67%
X20	3,15%	92,84%	88,79%	2,34%	37,85%	8,51%	0,26%	1,71%	35,90%	50,98%	0,11%
X21	4,18%	92,09%	91,33%	4,77%	8,77%	2,42%	0,59%	3,70%	9,86%	76,05%	3,15%
X22	2,10%	92,93%	93,97%	1,17%	0,83%	5,27%	0,73%	1,07%	0,86%	27,13%	1,08%
X23	2,17%	90,23%	88,78%	0,68%	47,32%	5,55%	0,0%	0,54%	44,87%	46,12%	0,75%
X24	1,03%	90,48%	86,34%	0,59%	14,58%	2,31%	0,0%	0,57%	10,50%	12,91%	7,49%
X25	2,28%	90,62%	89,76%	1,05%	55,31%	31,46%	0,30%	0,80%	53,58%	12,30%	0,44%
X26	2,76%	92,05%	84,78%	12,99%	26,81%	1,59%	0,31%	9,62%	21,26%	3,97%	0,04%

Table A2. Evaluation matrix (continued).

	K12	K13	K14	K15	K16	K17	K18	K19	K20	K21	K22
X1	13,72%	86,14%	84,66%	15,34%	91,20%	20,0%	80,0%	91,77%	1,19%	6,61%	10,30%
X2	3,28%	98,63%	86,81%	13,19%	90,02%	0,0%	0,0%	93,16%	3,46%	5,0%	5,81%
X3	4,39%	97,75%	81,85%	18,15%	92,72%	22,22%	77,78%	94,83%	2,14%	6,68%	3,24%
X4	1,14%	84,13%	77,81%	22,19%	91,54%	43,75%	56,25%	91,86%	0,79%	6,08%	3,27%
X5	3,91%	98,78%	81,41%	18,59%	91,36%	35,71%	64,29%	98,89%	6,69%	7,17%	6,73%
X6	6,49%	92,49%	80,20%	19,80%	91,09%	25,23%	74,77%	96,62%	11,36%	15,44%	7,51%
X7	3,88%	94,51%	84,93%	15,07%	91,06%	30,0%	70,0%	89,98%	0,72%	7,08%	3,99%
X8	1,58%	88,79%	72,0%	28,0%	91,12%	19,77%	80,23%	81,79%	0,28%	6,42%	3,99%
X9	1,09%	91,33%	88,64%	11,36%	92,18%	0,0%	100%	85,46%	2,16%	5,76%	5,83%
X10	0,0%	93,97%	95,05%	4,95%	92,06%	25,0%	75,0%	99,53%	84,29%	1,75%	20,83%
X11	46,19%	88,78%	100%	0,0%	90,57%	0,0%	100%	97,09%	4,62%	10,0%	5,53%
X12	0,76%	86,34%	84,64%	15,36%	92,51%	33,33%	66,67%	93,23%	7,29%	5,54%	5,88%
X13	8,43%	89,76%	91,94%	8,06%	92,73%	0,0%	100%	86,14%	0,9%	6,58%	6,12%
X14	0,0%	84,78%	88,64%	11,36%	94,61%	0,0%	100%	98,63%	3,61%	7,73%	2,94%
X15	11,23%	91,20%	86,35%	13,65%	88,17%	40,0%	60,0%	97,75%	26,99%	5,63%	12,41%
X16	3,13%	90,02%	90,63%	9,37%	90,54%	0,0%	100%	84,13%	0,38%	7,52%	9,78%
X17	0,0%	92,72%	88,64%	11,36%	92,68%	0,0%	100%	98,78%	0,86%	4,31%	3,85%
X18	0,0%	91,54%	88,64%	11,36%	86,05%	0,0%	100%	92,49%	1,08%	5,95%	9,30%
X19	0,24%	91,36%	84,47%	15,53%	93,54%	20,0%	80,0%	94,51%	2,75%	7,44%	4,58%
X20	1,59%	91,09%	82,29%	17,71%	92,84%	14,29%	85,71%	88,79%	1,02%	5,53%	3,28%
X21	2,45%	91,06%	89,21%	10,79%	92,09%	10,0%	90,0%	91,33%	0,79%	7,25%	9,26%
X22	0,43%	91,12%	95,88%	4,12%	92,93%	0,0%	100%	93,97%	2,48%	8,70%	7,36%
X23	0,60%	92,18%	79,92%	20,08%	90,23%	75,0%	25,0%	88,78%	0,66%	7,25%	2,98%
X24	5,93%	92,06%	75,70%	24,30%	90,48%	66,67%	33,33%	86,34%	0,75%	6,72%	5,0%
X25	1,32%	90,57%	71,15%	28,85%	90,62%	42,86%	57,14%	89,76%	1,03%	7,18%	3,95%
X26	22,94%	92,51%	79,84%	20,16%	92,05%	0,0%	100%	84,78%	1,83%	5,49%	6,07%